INDOOR AIR QUALITY ASSESSMENT

Henry E. Warren Elementary School
73 Fruit Street
Ashland, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
July 2006

Background/Introduction

At the request of Julian Doktor, staff member of the Henry E. Warren Elementary School (HWES), the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH), provided assistance and consultation regarding indoor air quality concerns at the HWES, 73 Fruit Street, Ashland, Massachusetts. The request was prompted by concerns of potential mold growth as a result of chronic roof leaks.

On May 6, 2005, a visit to conduct an assessment of the HWES was made by Michael Feeney, Director of CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program. The HWES is a one-story, tan, brick building constructed in 1961. Additions and renovations to the original building were made in 1992 (Map 1). The school is built at the bottom of a sloping hill on a concrete slab. Windows throughout the building are openable.

Methods

Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity were conducted with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Hnu, Model 102 Snap-on Photo Ionization Detector (PID). MDPH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

This school houses approximately 650 first through third grade students with approximately 90 staff members. Tests were taken during normal operations at the school. Results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in twenty-three out of forty-four areas surveyed, indicating inadequate air exchange in approximately fifty percent of the areas measured. It is also important to note that several classrooms with carbon dioxide levels below 800 ppm had windows open and/or were unoccupied or sparsely populated, which can greatly reduce carbon dioxide levels. (During full occupancy the carbon dioxide levels would be expected to be higher).

Fresh air in classrooms is supplied by unit ventilator (univent) systems. A univent draws air from outdoors through a fresh air intake located on the exterior wall of the building and returns air through an air intake located at the base of the unit (Figure 1). Fresh and return air are mixed, filtered, heated and provided to classrooms through a diffuser located on the top of the unit. Mechanical exhaust ventilation in classrooms is provided by wall-mounted exhaust vents ducted to rooftop exhaust fans. Univents and exhaust vents were deactivated and /or obstructed with items in a number of areas throughout the building. To function as designed, univents and exhaust vents must be activated and be free of obstructions. Without adequate supply and exhaust ventilation, excess heat and environmental pollutants can build up and lead to indoor air/comfort complaints.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room, while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing reportedly occurred over the summer 2005.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, see Appendix A.

Temperature measurements ranged from 72° F to 80° F, which were mostly within the MDPH recommended comfort range[1] (Table 1). The MDPH recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity measurements ranged from 25 to 49 percent, which were below the MDPH recommended comfort range in some areas. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. It is important to note however, that relative humidity measured indoors exceeded outdoor measurements (range 1-29 percent above). This increase in relative humidity can indicate that the exhaust system alone is not operating sufficiently to remove normal indoor air pollutants (e.g., water vapor from respiration). Moisture removal is important since the sensation of heat conditions increases as relative humidity increases (the relationship between temperature and relative humidity is called the heat index). As indoor temperature rises, the addition of more relative humidity

---

[1] Rooms with temperatures > 78° had windows open and are reflective of outdoor air temperature measured on the day of the assessment (81°),

will make occupants feel hotter. If moisture is removed, comfort is increased. Removal of moisture from the air, however, can have some negative effects. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Relative humidity levels in the building would be expected to drop during the winter months due to heating.

Microbial/Moisture Concerns

A number of rooms in the 1992 wing had water damaged ceiling tiles and were reported to have water damaged carpeting. Porous materials (e.g., ceiling tiles, carpet) that are wet repeatedly can serve as media for mold growth. The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy porous materials is not recommended.

The 1992 wing has a truncated mansard roof (Figures 2 and 3), with a flat roof fitted over the center of the building instead of one with a slight peak. Installed on the flat section of the roof are air handling units that provide mechanical ventilation for offices (Picture 1). Water damage was observed beneath the junction of the flat/sloped areas of the truncated mansard roof or at the junction between the original and 1992 wing. This would indicate that the transition between the flat and sloped areas of the roof have either missing or incomplete flashing. In general, where two dissimilar materials meet on the exterior of a building, the seam between them can serve as a point source for water penetration. The installation of flashing allows for water to transition from one surface to the next. Without proper flashing, water can penetrate through the seam resulting in water damage and potential mold growth.

It is also likely that the flat section of the roof has little or no drainage. Over time, the weight of the rooftop HVAC equipment will create a depression in the roof allowing water to pool. The roof appears to have a slight pitch, which would direct water (albeit inefficiently) to the sloped sections of the roof to be collected into a gutter/downspout system at the roof edge (Picture 2). The system then appears to drain water to a dry well located to the east of the 1992 wing (Picture 3). The amount of water emptied by the gutter/downspout system appears to be substantial, as demonstrated by the scoured ground/lack of grass beneath downspouts (Picture 4). Substantial amounts of water appear to overflow the gutters, as evidenced by scouring lines in the dirt directly beneath the roof edge (Picture 5). HWES staff reported that the ground to the east of the wing is prone to flooding, which may indicate that the dry well is not connected to the storm drain system.

Exterior wall systems should be designed to prevent moisture penetration into the building interior. An exterior wall system should consist of an exterior curtain wall. Behind the curtain wall is an air space that allows for water to drain downward and for the exterior cladding system to dry. At the base of the curtain wall should be weep holes that allow for accumulated water to drain from a wall system (Dalzell, J.R., 1955). Opposite the exterior wall and across the air space is a continuous, water-resistant material adhered to the back up wall that forms the drainage plane. The purpose of the drainage plane is to prevent moisture from crossing the air space and subsequently penetrating the interior of the building. The plane also directs moisture downwards toward the weep holes. The drainage plane can consist of a number of water-resistant materials, such as tarpaper, or in newer buildings, plastic wraps. The drainage plane should be continuous. Materials (e.g., flashing) are typically installed as transitional surfaces to direct water to weep holes where breaks in the drainage plane exist (e.g., window systems, door systems and univent fresh air intakes). If the drainage plane is discontinuous, missing flashing or lacking air space, water may accumulate inside the wall cavity and lead to moisture penetration into the building.

Weep holes are customarily installed at or near the foundation slab/exterior wall system junction (Figure 4). Failure to install weep holes in brickwork or weep holes below grade will allow water to accumulate in the base of walls, resulting in seepage and possible moistening of building components (Figure 5). The exterior of the HWES consists of a traditional brick wall. An examination of the exterior brick walls outside of classrooms 2 through 11 was conducted to identify the location and condition of weep holes. Weep holes were found approximately at slab level. Of note is that each weep hole was blocked with a cloth/wick material, particularly rooms 9 through 11. Wicks were originally installed to enhance water movement from the drainage plane. Over time, sediment accumulation turns the wick into a stopper, which prevents water drainage from the exterior wall system. It is not recommended to "use ropes or tubes for weep [hole]s" (Nelson, P.E., 1999). Weep holes need to be open to facilitate the drying of exterior walls.

Other IAQ Evaluations

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, MDPH staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were non-detect or ND (Table 1). Carbon monoxide levels measured in the school were also ND.

As previously mentioned, the US EPA also established NAAQS for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particulate levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 15 $\mu g/m^3$ (Table 1). PM2.5 levels measured indoors ranged from 3 to 28 $\mu g/m^3$, which were below the NAAQS PM2.5 level of 65 $\mu g/m^3$ in all areas. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors (as was the case in the cafeteria).

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were ND (Table 1). Indoor TVOC measurements throughout the building were also ND.

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC-containing products. While no measurable TVOC levels were detected in the indoor environment, VOC-containing materials were noted. Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

A number of other conditions that can potentially affect indoor air quality were also observed. Reused food containers and poorly stored food can create conditions to attract pests into the building. Under current Massachusetts law (effective November 1, 2001), the principles of integrated pest management (IPM) must be used to remove pests in state buildings (Mass Act, 2000). Pesticide use indoors can introduce chemicals into the indoor environment that can be sources of eye, nose and throat irritation. The reduction/elimination of pathways/food sources that are attracting insects should be the first step taken to prevent or eliminate infestation.

In an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs. Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and to off-gas TVOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix B (NIOSH, 1998).

Finally, was the amount of materials stored inside classrooms throughout the school. Items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items, (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Dust can be irritating to eyes, nose and respiratory tract. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

Conclusions/Recommendations

Classrooms and offices in the 1992 wing appear to be damaged from chronic roof leaks detailed in this assessment. Until drainage of the roof is addressed as described in this report and recommendations are implemented, water damage is likely to be a recurring problem. In view of the findings at the time of the assessment, the following recommendations are made:

1. Consider consulting a building engineer on the appropriate manner by which water drains from the roof above the area of chronic water damage.
2. Remove wicks from all weep holes and clear obstructions to walls to maximize water drainage from exterior wall systems. Install appropriate media in the weep holes to prevent insect migration.
3. Continue to work with concerned individuals to identify and address IAQ/mold concerns. Should mold issues recur, remove mold-contaminated materials (i.e., ceiling tiles and chronically water damaged carpets) in a manner consistent with recommendations found in "Mold Remediation in Schools and Commercial Buildings" published by the US EPA (2001). Copies of this document can be downloaded from the US EPA website at: http://www.epa.gov/iaq/molds/mold_remediation.html.
4. Once repairs are made, replace water damaged ceiling tiles. Examine the area above and around water-damaged areas for mold growth. Disinfect areas with an appropriate antimicrobial as needed.
5. To maximize air exchange, operate both supply and exhaust ventilation continuously during periods of school occupancy.
6. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to

minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

7. Discontinue the use of tennis balls on chairs to prevent latex dust generation. Alternative "glides" can commonly be purchased from office supply stores; see Picture 6 for an example.
8. Use the principles of integrated pest management (IPM) to prevent pest infestation. A copy of the IPM recommendations (MDFA, 1996) can be downloaded from the following website: http://www.state.ma.us/dfa/pesticides/publications/IPM_kit_for_bldg_mgrs.pdf.
9. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning.
10. Consider adopting the US EPA document, *Tools for Schools* (US EPA, 2000b), as a means to maintaining a good indoor air quality environment in the building. This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.
11. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. Copies of these materials are located on the MDPH's website: http://www.state.ma.us/dph/beha/iaq/iaqhoFtme.htm.

References

ACGIH. 1989. Guidelines for the Assessment of Bioaerosols in the Indoor Environment. American Conference of Governmental Industrial Hygienists, Cincinnati, OH.

ASHRAE. 1989. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-1989

BOCA. 1993. The BOCA National Mechanical Code/1993. 8th ed. Building Officials and Code Administrators International, Inc., Country Club Hill, IL

Dalzell, J.R. 1955. *Simplified Masonry Planning and Building*. McGraw-Hill Book Company, Inc. New York, NY.

Mass. Act. 2000. An Act Protecting Children and families from Harmful Pesticides. 2000 Mass Acts c. 85 sec. 6E.

MDPH. 1997. Requirements to Maintain Air Quality in Indoor Skating Rinks (State Sanitary Code, Chapter XI). 105 CMR 675.000. Massachusetts Department of Public Health, Boston, MA.

Nelson, P.E. 1999. Brick Cavity Walls and Associated Flashings. Third Annual Westford Symposium on Building Science Course Book. Building Science Corporation, Westford, MA.

NIOSH. 1998. Latex Allergy A Prevention. National Institute for Occupational Safety and Health, Atlanta, GA.

NIOSH. 1997. NIOSH Alert Preventing Allergic Reactions to Natural Rubber latex in the Workplace. National Institute for Occupational Safety and Health, Atlanta, GA.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R 1910.1000 Table Z-1-A.

Sanford. 1999. Material Safety Data Sheet (MSDS No: 198-17). Expo® Dry Erase Markers Bullet, Chisel, and Ultra Fine Tip. Sanford Corporation. Bellwood, IL.

SBAA. 2001. Latex In the Home And Community Updated Spring 2001. Spina Bifida Association of America, Washington, DC.
Http://www.sbaa.org/html/sbaa_mlatex.html

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0.

SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning

US EPA. 2000a. National Ambient Air Quality Standards (NAAQS). US Environmental Protection Agency, Office of Air Quality Planning and Standards, Washington, DC. http://www.epa.gov/air/criteria.html.

US EPA. 2000b. Tools for Schools. Office of Air and Radiation, Office of Radiation and Indoor Air, Indoor Environments Division (6609J). EPA 402-K-95-001, Second Edition. http://www.epa.gov/iaq/schools/tools4s2.html

US EPA. 2001. "Mold Remediation in Schools and Commercial Buildings". Office of Air and Radiation, Indoor Environments Division, Washington, DC. EPA 402-K-01-001. March 2001. Available at: http://www.epa.gov/iaq/molds/mold_remediation.html

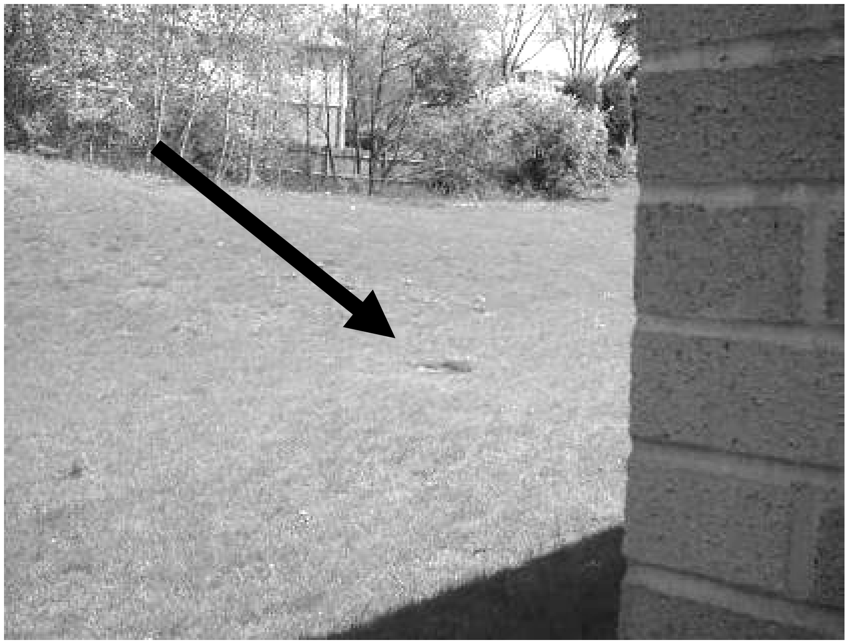
Picture 1

HVAC Equipment on the Flat Roof, New Wing

Picture 2

Gutter/Downspout System

Picture 3



Dry Well in Lawn to East of New Wing

Picture 4

Ground Scouring and Lack Of Grass beneath Downspouts

Picture 5

Lines in Dirt Directly Beneath the Roof Edge

Picture 6

"Glides" for Chair Legs that can be used as an Alternative to Tennis Balls

Henry E. Warren School | **Indoor Air Results**

73 Fruit Street, Ashland, MA 01721 | **Date: 05/05/2006**

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
outside		81	25	379	ND	ND	15				
library	0	75	33	604	ND	ND	7	Y # open: 0 # total: 0	Y (off)	Y (off)	
nurse's office	1	74	36	801	ND	ND	16	Y # open: 0 # total: 0	Y ceiling	Y ceiling	Hallway DO,
main office	4	74	34	727	ND	ND	16	Y # open: 2 # total: 2	Y ceiling	Y ceiling	
31	6	76	32	591	ND	ND	8	N	plant(s)		AP, cleaners, FC re-use, items.
11	21	75	40	961	ND	ND	14	Y # open: 0 # total: 0	Y univent	Y wall	water damage, other.
10	14	74	43	843	ND	ND	16	Y # open: 0 # total: 0	Y univent (off)	Y wall (off)	Hallway DO, cleaners, items, nests.

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Henry E. Warren School **Indoor Air Results**

73 Fruit Street, Ashland, MA 01721 **Date: 05/05/2006**

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
26	21	78	37	1320	ND	ND	10	Y # open: 1 # total: 4	Y univent furniture	Y (off) furniture	DEM.
21	19	77	34	872	ND	ND	10	Y # open: 0 # total: 0	Y univent	Y wall (off)	TB.
27	23	79	29	709	ND	ND	11	Y # open: 3 # total: 6	Y univent	Y wall (off) furniture	Hallway DO, DEM.
29	19	79	33	997	ND	ND	13	Y # open: 1 # total: 6	Y univent	Y wall (off)	Hallway DO, DEM, TB.
9	22	74	40	966	ND	ND	13	Y # open: 1 # total: 6	Y univent	Y wall furniture	Hallway DO, cleaners.
8	16	75	43	1337	ND	ND	13	Y # open: 0 # total: 0	Y univent	Y wall	Hallway DO,
7	14	75	37	778	ND	ND	9	Y # open: 8 # total: 8	Y univent	Y wall	DEM.

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Henry E. Warren School **Indoor Air Results**

73 Fruit Street, Ashland, MA 01721 **Date: 05/05/2006**

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (μg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
5	20	75	38	912	ND	ND	9	Y # open: 2 # total: 8	Y univent	Y wall	Hallway DO,
small group 1	1	74	31	567	ND	ND	5	Y # open: 0 # total: 0	Y ceiling	Y ceiling	Hallway DO, #CT-mold: 3.
Art	1	76	32	618	ND	ND	5	Y # open: 0 # total: 0	Y ceiling		Hallway DO, #CT-mold: 6.
small group 3	2	76	26	502	ND	ND	3	Y # open: 2 # total: 2	Y ceiling	Y ceiling	WD-ceiling, #WD-CT: 5, other 1 light fan.
small group 2	0	76	27	518	ND	ND	5	N			
small group 5	3	80	25	486	ND	ND	11	Y # open: 1 # total: 1	Y wall	Y ceiling	
small group 6	0	79	29	603	ND	ND	16	Y # open: 0 # total: 0	Y wall	Y ceiling	Hallway DO,

ppm = parts per million
μg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Henry E. Warren School

73 Fruit Street, Ashland, MA 01721

Indoor Air Results

Date: 05/05/2006

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
supply group 7	0	79	27	499	ND	ND	13	N	Y wall	Y ceiling	Hallway DO,
small group 8	3	78	27	554	ND	ND	9	Y # open: 0 # total: 0	Y ceiling	Y wall	TB, items.
Teacher room	13	80	31	739	ND	ND	17	Y # open: 1 # total: 4	Y	N	local AC, food use/storage, wet toner copier/Risograph.
Photocopier room	0	80	25	457	ND	ND	12	N	Y	Y	Hallway DO, WD-ceiling, #WD-CT: 4, wet toner copier/Risograph.
13	21	76	37	1015	ND	ND	13	N	Y univent plant(s)	Y wall boxes	
9	6	76	33	662	ND	ND	13	Y # open: 2 # total: 2	Y wall	Y ceiling	DEM, TB, cleaners.
18	23	76	44	1439	ND	ND	16	Y # open: 0 # total: 0	Y univent	Y wall furniture	Hallway DO, DEM, TB, cleaners.

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Henry E. Warren School

73 Fruit Street, Ashland, MA 01721

Indoor Air Results

Date: 05/05/2006

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (μg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
17	24	76	37	787	ND	ND	16	Y # open: 4 # total: 4	Y univent	Y wall furniture	Hallway DO, DEM, TB.
16	21	76	40	979	ND	ND	20	Y # open: 3 # total: 6	Y univent	Y wall furniture	Hallway DO, DEM, TB, cleaners.
15	22	77	41	1116	ND	ND		Y # open: 0 # total: 0	Y univent items	Y wall boxes	Hallway DO, cleaners, items.
14	21	77	39	1165	ND	ND	16	Y # open: 0 # total: 0	Y univent boxes items furniture	Y wall furniture	Hallway DO, DEM, food use/storage, wall to wall carpet.
12	26	76	34	670	ND	ND	14	Y # open: 3 # total: 4	Y univent dust/debris furniture	Y	DEM, cleaners.
4	0	76	30	470	ND	ND	4	Y # open: 0 # total: 0			Hallway DO.

ppm = parts per million
μg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Henry E. Warren School **Indoor Air Results**

73 Fruit Street, Ashland, MA 01721 **Date: 05/05/2006**

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
3	0	75	37	660	ND	ND	4	Y # open: 0 # total: 0	Y univent	Y wall	Hallway DO,
6	20	74	40	829	ND	ND	6	Y # open: 0 # total: 0	Y univent	Y wall furniture	Hallway DO, #WD-CT: 9, DEM, other - books.
2	1	75	32	571	ND	ND	7	Y # open: 0 # total: 0	Y univent	Y wall	Hallway DO, DEM, cleaners.
32	1	72	49	854	ND	ND	27	Y # open: 0 # total: 0	N	N	
25	21	74	49	1284	ND	ND	25	Y # open: 1 # total: 4	Y univent	Y wall furniture	Hallway DO, DEM, TB.
24	15	75	47	1215	ND	ND	28	Y # open: 0 # total: 0	Y univent	Y closet (off) boxes	Hallway DO, DEM, items.
23	0	75	45	1365	ND	ND	28	Y # open: 0 # total: 0	Y univent	Y (off)	Hallway DO, DEM.

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Henry E. Warren School

73 Fruit Street, Ashland, MA 01721

Indoor Air Results

Date: 05/05/2006

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (μg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
22	20	76	42	1146	ND	ND	28	Y # open: 1 # total: 4	Y univent	Y wall (off) furniture	Hallway DO, DEM, cleaners.
20	1	75	39	902	ND	ND	19	Y # open: 0 # total: 0	Y univent	Y wall furniture	Hallway DO, DEM, TB, cleaners.
21	18	76	43	1164	ND	ND	17	N	Y univent boxes	Y wall boxes furniture	DEM, cleaners.
19	19	75	40	938	ND	ND	19	Y # open: 2 # total: 4	Y univent	Y wall	TB.

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

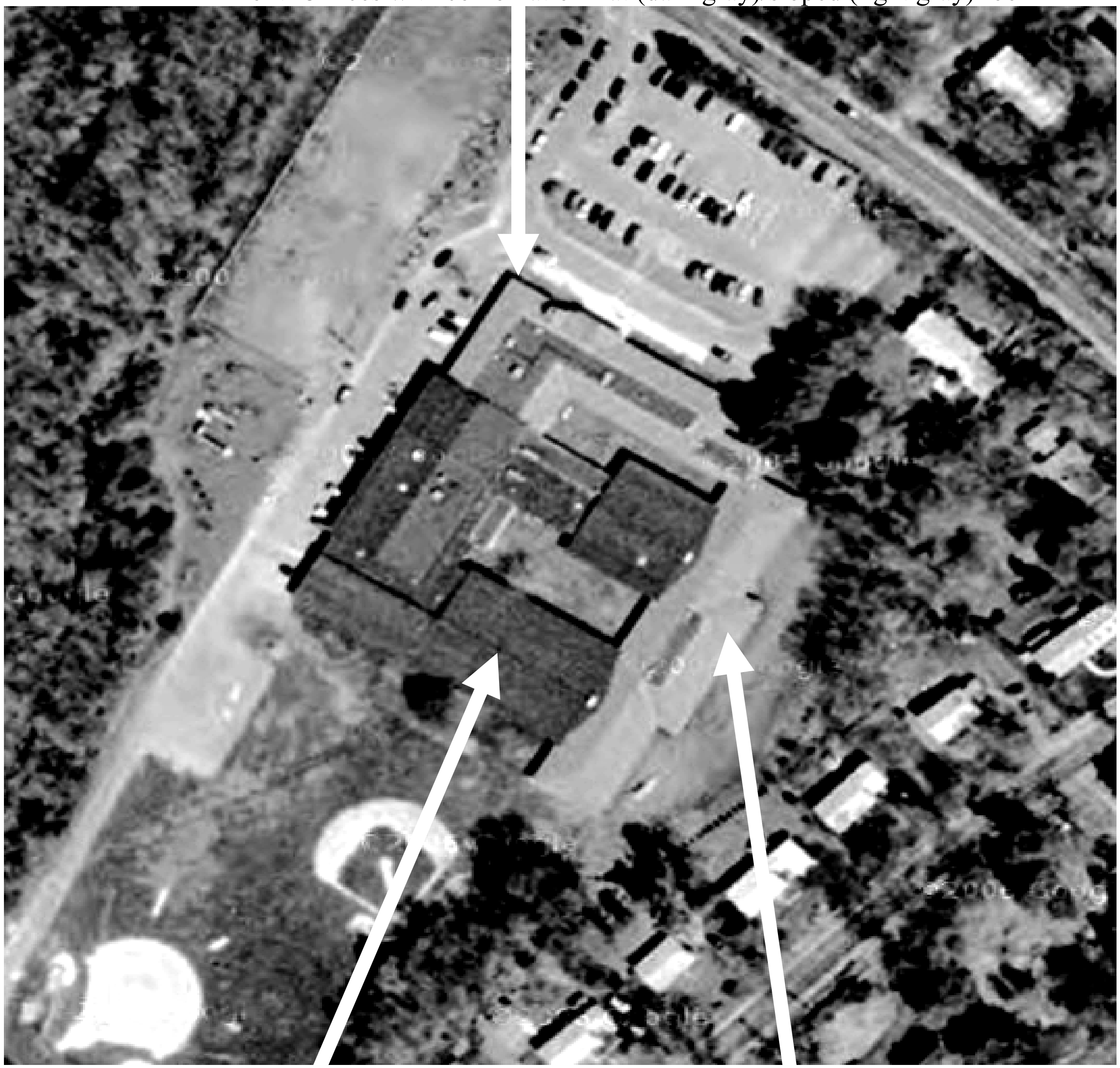
Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Map 1
Henry E. Warren Elementary School Aerial View

Front Offices with combination flat (dark gray)/sloped (light gray) roof



Original Wing

1992 Addition

Figure 2
Mansard roof, general shape

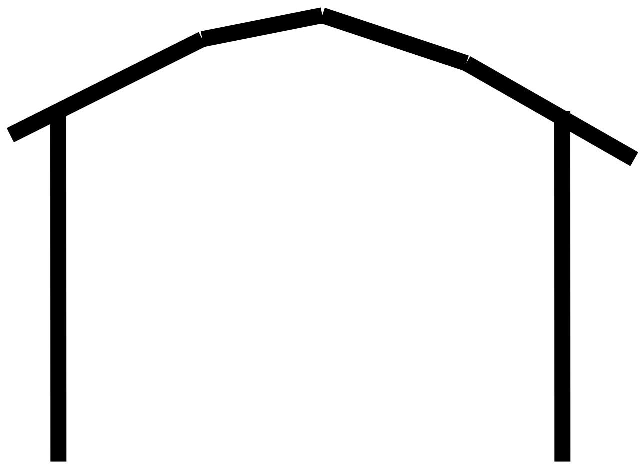


Figure 3
Truncated Mansard roof, HWES

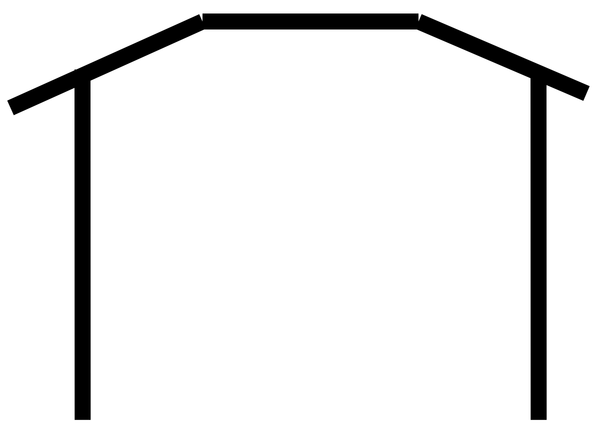


Figure 4
The Function of the Drainage Plane and Weep Holes to Drain Water from the Wall System, Prevent Moisture Penetration into the Interior

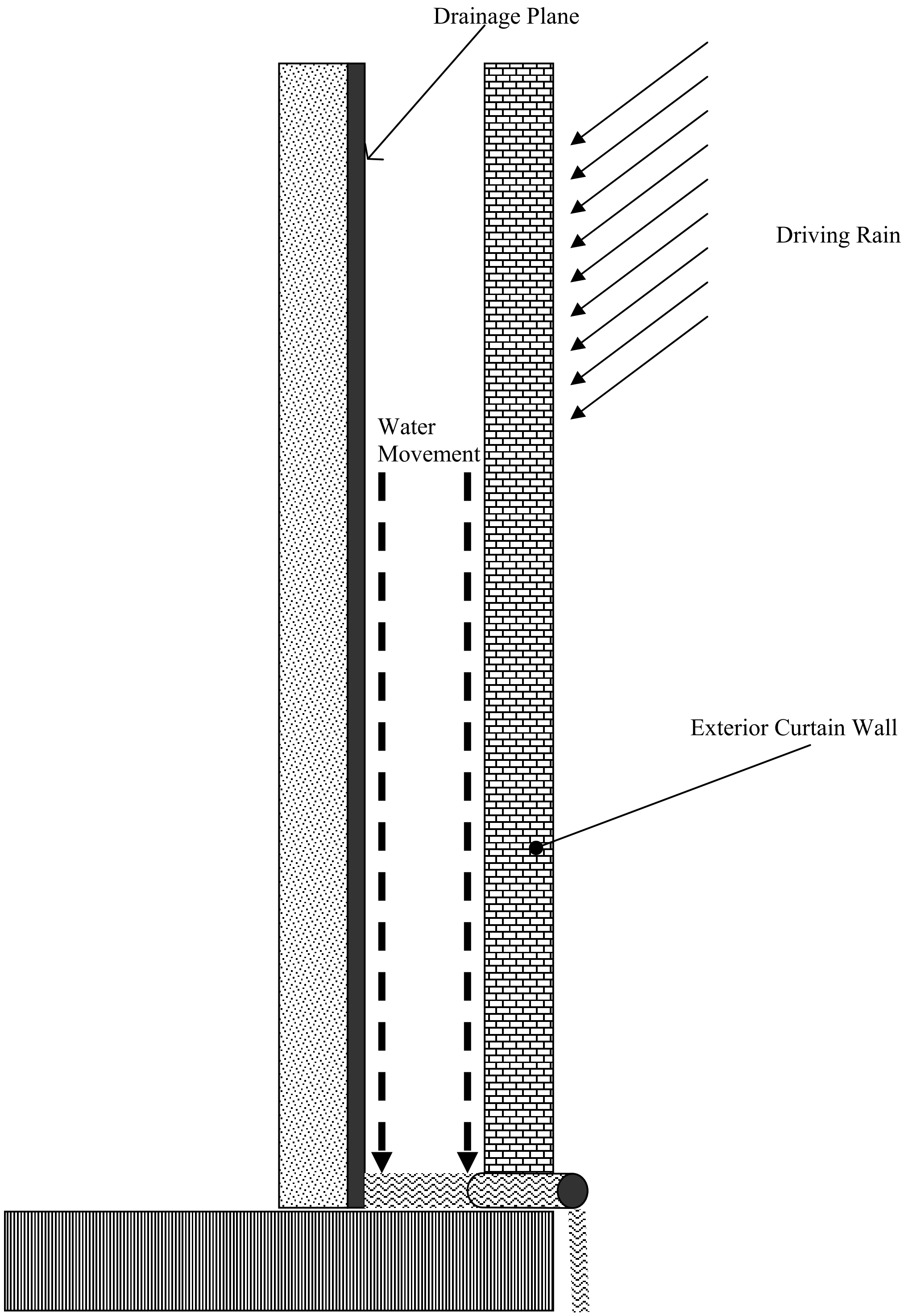


Figure 5
Weep Hole Blocked with Wick and Water Accumulation in the Drainage Plane